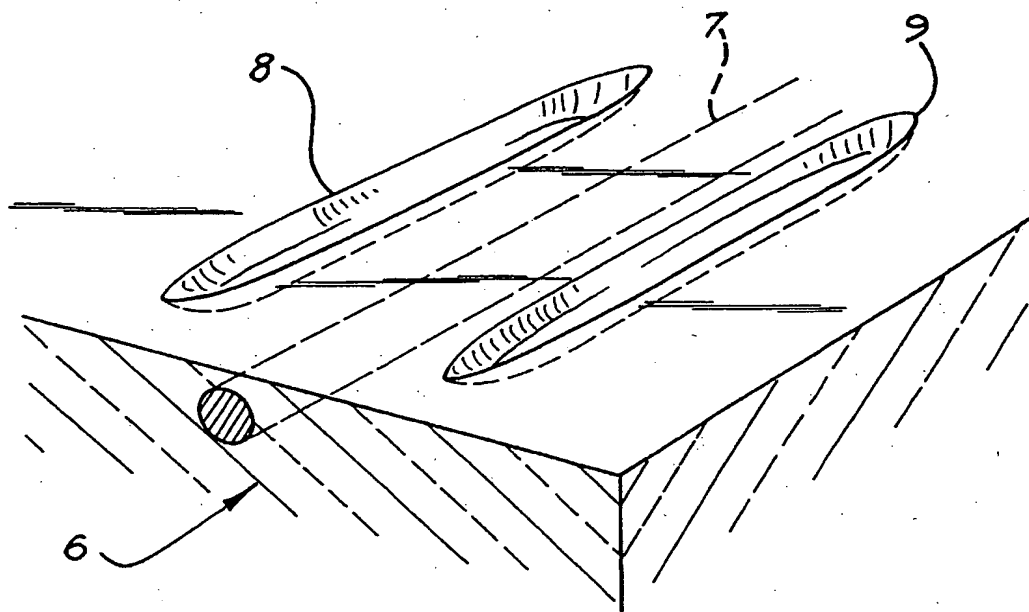




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : G02B 6/10, B23K 26/36	A1	(11) International Publication Number: WO 00/48024 (43) International Publication Date: 17 August 2000 (17.08.00)
(21) International Application Number: PCT/AU00/00099 (22) International Filing Date: 14 February 2000 (14.02.00) (30) Priority Data: PP 8655 12 February 1999 (12.02.99) AU (71) Applicant (for all designated States except US): THE UNIVERSITY OF SYDNEY [AU/AU]; Parramatta Road, Sydney, NSW 2006 (AU). (72) Inventors; and (75) Inventors/Applicants (for US only): CANNING, John [AU/AU]; 10 Francis Street, Carlton, NSW 2218 (AU). ASLUND, Mattias [SE/AU]; 167 The Kingsway, Cronulla, NSW 2230 (AU). (74) Agent: GRIFFITH HACK; G.P.O. Box 4164, Sydney, NSW 2001 (AU).		(81) Designated States: AU, CA, JP, KR, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>

(54) Title: LASER ABLATION OF WAVEGUIDE STRUCTURES**(57) Abstract**

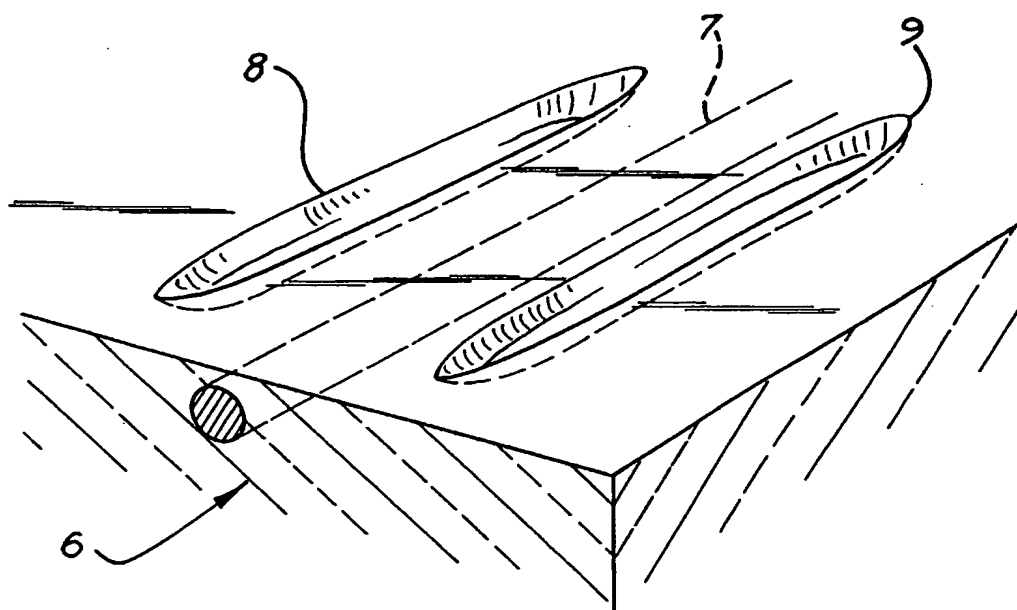
A method of processing an optical device incorporating a waveguide, the method comprising the step of utilizing a laser to heat a surface of the device to alter an optical characteristic of the waveguide, wherein the power density of the laser is selected to effect ablation.



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : G02B 6/10, B23K 26/36	A1	(11) International Publication Number: WO 00/48024 (43) International Publication Date: 17 August 2000 (17.08.00)
(21) International Application Number: PCT/AU00/00099 (22) International Filing Date: 14 February 2000 (14.02.00) (30) Priority Data: PP 8655 12 February 1999 (12.02.99) AU (71) Applicant (for all designated States except US): THE UNIVERSITY OF SYDNEY [AU/AU]; Parramatta Road, Sydney, NSW 2006 (AU). (72) Inventors; and (75) Inventors/Applicants (for US only): CANNING, John [AU/AU]; 10 Francis Street, Carlton, NSW 2218 (AU). ASLUND, Mattias [SE/AU]; 167 The Kingsway, Cronulla, NSW 2230 (AU). (74) Agent: GRIFFITH HACK; G.P.O. Box 4164, Sydney, NSW 2001 (AU).		(81) Designated States: AU, CA, JP, KR, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>

(54) Title: LASER ABLATION OF WAVEGUIDE STRUCTURES



(57) Abstract

A method of processing an optical device incorporating a waveguide, the method comprising the step of utilizing a laser to heat a surface of the device to alter an optical characteristic of the waveguide, wherein the power density of the laser is selected to effect ablation.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

- 1 -

LASER ABLATION OF WAVEGUIDE STRUCTURESField of the Invention

The present invention relates broadly to laser ablation (or alternatively sometimes referred to as laser etching, hereinafter referred to as ablation) processing of waveguide structures.

Background of the Invention

During the construction of optical waveguide devices, it is common that changes associated with a particular construction step occur which may affect the operational characteristics of the devices. For example, optical devices are often constructed utilizing an adaptation of semiconductor fabrication techniques and can commonly include a number of layers constructed on a silicon substrate. As a result of differential thermal expansion coefficients of the materials, various compressive stresses are induced during normal operating conditions. These stresses can have the effect of changing the operational characteristics of any device formed on the substrate. In particular, the compressive stresses can often give rise to anisotropic birefringent properties in optical waveguides which can substantially effect their operation.

Interim solutions suggested have included techniques such as employing complex hybrid technologies where bulk polarizing elements are slotted into an optical chip and set to compensate for birefringence, or providing time consuming chemical etching steps for etching strain relieving grooves on either side of a waveguide. Treatment via a UV laser to create damage at the substrate which leads to compensating stresses has also been suggested, however, the utilization of UV laser treatment has significant problems in that the lasers are expensive and can be unreliable in a manufacturing environment. They typically require constant skilled maintenance.

Summary of the Invention

The present invention provides a method of

- 2 -

processing an optical device incorporating a waveguide, the method comprising the step of utilizing a laser to heat a surface of the device, to alter an optical characteristic of the waveguide, and wherein the power density of the
5 laser is selected to effect surface ablation.

The laser may comprise a carbon dioxide laser source.

The method may be utilized to alter the birefringent properties of the waveguide, e.g. the TM and
10 TE birefringent modes may be substantially aligned.

The step method may further comprise the step of may further comprise masking the surface with a thermally conductive material having an aperture defined therein to limit exposure of the device to the laser.

15 The device may comprise a sensor.

The method may further comprise the step of depositing a material layer on the surface. Accordingly, the method itself may be utilised to form the device. The device may eg. comprise a semiconductor device or a SiO₂/Si
20 planar waveguide device.

Step of depositing the material layer may comprise depositing the material layer on portions of the surface affected by the ablation.

The material layer may be provided as an
25 electrode for electrically contacting the device.

The method may further comprise the step of mounting a further component in a groove formed in the surface as a result of the ablation. The further component may comprise a modulator for modulating a characteristic of
30 the device.

The method may be conducted at different locations of the device so as to form an optical structure. The optical structure may comprise a grating structure. The optical structure may comprise a polarisation filter.

35 The method may be used to diminish UV induced changes present in the waveguide.

The device may comprise an optical fibre.

- 3 -

The method may be utilised to mark the device by way of the ablation.

The laser may comprise a semiconductor laser operating at a wavelength of more than about 1.8 micro
5 metre. This wavelength range may be preferable where the surface of the device comprises SiO₂.

The method may further comprise the step of providing an absorber material to facilitate the heating of the surface of the device.

10 The invention may alternatively be defined as providing an device incorporating a waveguide, wherein the device has been processed utilising a laser to heat a surface of the device, to alter an optical characteristic of the waveguide, and wherein the power density of the laser is
15 selected to effect surface ablation.

Brief Description of the Drawings

Notwithstanding any other forms which may fall within the scope of the present invention, preferred forms of the invention will now be described, by way of example
20 only, with reference to the accompanying drawings in which:

Fig. 1 illustrates schematically the operation of the method of the preferred embodiment;

Fig. 2 illustrates the ablation of a wafer surface;

25 Fig. 3 illustrates the change and effective index in an experiment utilizing the preferred embodiment;

Fig. 4 illustrates a further change in the effective index of an experiment utilizing the preferred embodiment;

30 Fig. 5 illustrates the initial profile of a Mach-Zehnder (MZ) interferometer prior to application of preferred embodiment showing both the TM and TE modes;

Fig. 6 illustrates the spectral response for TE and TM modes of a MZ interferometer after application of
35 the preferred embodiment for the device of Fig. 6;

Fig. 7 illustrates an alternative form of processing a wafer;

- 4 -

Fig. 8 illustrates the process of ablation around a core of a waveguide;

Fig. 9 illustrates the utilization of ablation in changing the device characteristics of a waveguide;

5 Fig. 10 illustrates the utilization of ablation in conjunction with deposition of further layers on a wafer; and

Fig. 11 illustrates the construction of a long period lossy grating.

10 Description of Preferred and Other Embodiments

In the preferred embodiment, an inexpensive and relatively compact CO₂ laser device is utilized to provide mid infrared laser processing of a waveguide structure so as to obtain both birefringence compensation and tuning of
15 optical components. The processing set up is illustrated schematically in Fig. 1 wherein a waveguide 3 is subjected to ablation utilizing a CO₂ laser 5. An example of the ablation processing is illustrated in Fig. 2 wherein a waveguide 6 having a internal core 7 is processed so as to
20 include ablation channels 8, 9. In a first example, the CO₂ laser was used to enhance the device characteristics of an asymmetric Mach-Zehnder (MZ) interferometer fabricated utilizing hollow-cathode PECVD techniques.

The mid-IR radiation was used to thermally relax
25 stresses at the core and substrate as well as affect a change in the refractive index. At sufficiently high temperatures, the core and cladding waveguide glasses can be softened, melted and vaporised. These ablation processes themselves can be used to generate faster
30 relaxation than would otherwise be possible as well as provide a source of polarisation dependent loss for energy stripping within waveguides for functions such as optical attenuators, and for other more classical applications, including the laser ablation of stress-relieving grooves.
35 Most heating was found to occur through non-radiative transfer of absorbed light into vibrational modes of the silica molecule.

- 5 -

For given exposures utilized in experiments, the substrate temperature was thought to be approximately the same as that induced at the surface. The laser was operated initially with unfocussed 10W of CW power (-
5 140W/cm²). When the laser was later focused, temperatures readily exceeding the melting point of silica were achieved resulting in laser vaporisation and ablation.

Since the asymmetric MZ spectral response is characteristic of the interferometer established between
10 the input and output couplers, birefringence compensation, as measured by matched TE and TM spectra (the TM identified to have a higher effective index by writing a weak Bragg grating in a straight waveguide manufactured on the same wafer), can be achieved between the two couplers. From an
15 experimental point of view, if true birefringence reduction in this region is demonstrated, the change in TE and TM notch wavelength due to an increase in effective index must be such that they converge when processing the longer arm, and diverge when processing the shorter arm. The reverse
20 is the case for a decrease in refractive index. Otherwise, spectral compensation of polarisation is possible within a MZ whilst actually worsening the intrinsic polarisation dispersion. When convergence is achieved, then the
25 feasibility of polarisation compensation can be established which is generally applicable to other optical components and straight waveguides as well as the asymmetric MZ device chosen here.

In the experiments to determine the parameters of operation, optical spectra were taken, of the MZ device
30 using a broadband erbium-doped fibre amplifier (EDFA) and a spectrum analyser with a resolution of 0.05nm, limiting the birefringence splitting which can be measured to -1×10^{-5} .

In initial experiments, the longer arm of a MZ device (12 μ m SiO₂ cladding and buffer layers, 4x5 μ m GeO₂-
35 doped core, $\Delta n = 0.01$) was processed for testing and confirmation of the concept. Measurements were taken at intervals after briefly halting the exposure at fixed times

- 6 -

since the fibre coupling was increasingly affected by longer exposures. It was noted that both TE and TM shifted to longer wavelengths indicating an increase in refractive index. The TE effective index eventually increased more rapidly such that the splitting was reduced as shown in Fig. 4 which shows the change in wavelength splitting between TE and TM eigenstate with exposure to unfocussed light. Initially, however, as shown in Fig. 3, an increase in the splitting observed. We believe is related to an initial increase in compressive stress and subsequent compaction of the core glass. The magnitude of reduction is sufficient to allow compensation of birefringence in most planar silica-on-silicon devices where the splitting is much lower than the device chosen here. Further, this value is unsaturated.

The power density of the CO₂ laser was then increased to -1.3kW/cm^2 by focussing to a $100\mu\text{m}$ spot size such that we exceed the threshold necessary for vaporisation for an exposure of less than 0.2s. Ablation was confirmed under an optical microscope after gently cleaving through one damage region of the surface. By controlling the duration of the exposure it was possible to control the depth to which material is removed. The spectral responses when exposing the longer arm were found to shift to shorter wavelengths indicating a decrease in refractive index. However, the TM state was found to decrease more rapidly resulting in a large drop in the birefringence splitting. The decrease in refractive index and the localised ablation indicates that in this case dilation and stress compensation or relaxation at the core are the main factors responsible for the reduction in birefringence. Fibre coupling is significantly more stable (an important advantage for *in-situ* monitoring) and the process is clearly more efficient than thermal annealing of the material. This will affect the effective propagation constants for each polarisation state as well as introduce some polarisation dependent loss. The result is that this

- 7 -

can be used to achieve balancing of the optical energy for each eigenstate and hence result in a matched and improved spectral response of the device. Fig. 4 shows the change in effective index as a function of shots fired in the same region and shows the convergence of birefringence when exposing the longer arm. It was noted that subsequent successive shots on the same region did not contribute any further. Indeed a small reversal was observed. Exposing the shorter arm showed spectral divergence, as expected if polarisation compensation has been achieved.

The spectral response for a second device utilized in experiments (essentially a polarisation splitter) prior to irradiation is shown in Fig. 5. The poor fringe contrast and the difference between TE and TM responses indicates that the input coupler is polarisation sensitive and that different amounts of light are split for each eigenstate. As a result, the intensity of light in each arm is not equal leading to poor fringe contrast upon recombination at the output coupler, particularly in this case of the TE state. The polarisation sensitivity between couplers is very difficult to eliminate completely in silica-on-silicon systems where strain is not readily removed. Fig. 6 illustrates the end results on the device once the process of irradiation ablation was optimised. An improvement in fringe contrast to 20dB for both TE and TM states was achieved after five shots along the longer arm (power density $\sim 10\text{kW}/\text{cm}^2$). The total increase in loss necessary to balance the polarisation states in this particular device was -0.12 dB for TM and -1.2dB for TE.

A number of further modifications and applications of the aforementioned technique are possible. Firstly, the utilisation of the CO_2 laser can be refined as illustrated in Fig. 7 by utilizing a metal plate containing a slot with the metal plate acting as a heat sink so as to extract heat from the laser beam outside specific locations. In this manner, more refined processing of the waveguide can be achieved.

- 8 -

Secondly, the ablation of the waveguide can also be extended, as shown in Fig. 8, to the area surrounding the core 25. This can be utilized to effect the operation of the core and the overall device. For example, in Fig. 5 9, there is illustrated the utilization of ablation to form a refined surface 30 which can be utilized to provide for more accurate sensing by the core 31. Further, the ablation of the surface can be utilized in the construction of complex semi-conductor devices having predetermined 10 operational characteristics. For example, in Fig. 10, there is illustrated the example of deposition of a subsequent layer 33 which can comprise zinc oxide, BiTlO_3 or the like so as to provide for a functional semiconductor device.

15 A further example refinement is illustrated in Fig. 11 where a series of ablations 40-42 are written at regular intervals along a core 43 so as to provide for a long period "loss" grating structure.

Other applications can include modification of 20 polarization controllers and attenuators etc.

The aforementioned laser process has a number of other uses. In particular, it can be used to provide for accelerated aging of components by means of CO_2 thermal heating of optical devices such as UV processed gratings 25 formed on a planar waveguide. The accelerated aging can provide for improved operational characteristics and can include precise localised aging of components. Further, the thermal annealing can be utilized to anneal out the UV processing of portions of a previously processed waveguide. 30 This can be taken to the extent of almost totally annealing out the UV processing effect.

Further, the above processing steps are also directly applicable to fibre devices.

It would be appreciated by a person skilled in the 35 art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of

- 9 -

the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

- 10 -

We Claim:

1. A method of processing an optical device incorporating a waveguide, the method comprising the step of:
 - 5 - utilizing a laser to heat a surface of the device, to alter an optical characteristic of the waveguide, and wherein the power density of the laser is selected to effect surface ablation.
2. A method as claimed in claim 1 wherein the
10 laser comprises a carbon dioxide laser source.
3. A method as claimed in any one of the preceding claims wherein the method is utilized to alter the birefringent properties of the waveguide.
4. A method as claimed in claim 3 wherein the
15 TM and TE birefringent modes are substantially aligned by the method.
5. A method as claimed in any one of the preceding claims further comprising the step of masking the surface with a thermally conductive material having an
20 aperture defined to minimise exposure of the device to the laser.
6. A method as claimed in any one of the preceding claims wherein the device comprises a sensor.
7. A method as claimed in any one of the
25 preceding claims further comprising the step of:
 - depositing a material layer on the surface.
8. A method as claimed in claim 7, wherein the step of depositing the material layer comprises depositing
30 the material layer on portions of the surface affected by the ablation.
9. A method as claimed in any one of the preceding claims further comprising the step of:
 - mounting a further component in a groove
35 formed in the surface as a result of the ablation.
10. A method as claimed in claim 7 or 8, wherein the material layer is provided as an electrode for

- 11 -

electrically contacting the device.

11. A method as claimed in claim 9, wherein the further component comprises a modulator for modulating a characteristic of the device.

5 12. A method as claimed in any one of the preceding claims wherein the step of utilising the laser to heat the surface is conducted at different locations of the device so as to form an optical structure.

10 13. A method as claimed in claim 12, wherein the optical structure comprises a grating structure.

14. A method as claimed in claims 12 or 13, wherein the optical structure comprises a polarisation filter.

15 15. A method as claimed in any one of the preceding claims wherein the method is used to diminish UV induced changes present in the waveguide.

16. A method as claimed in any one of the preceding claims wherein the device comprises an optical fibre.

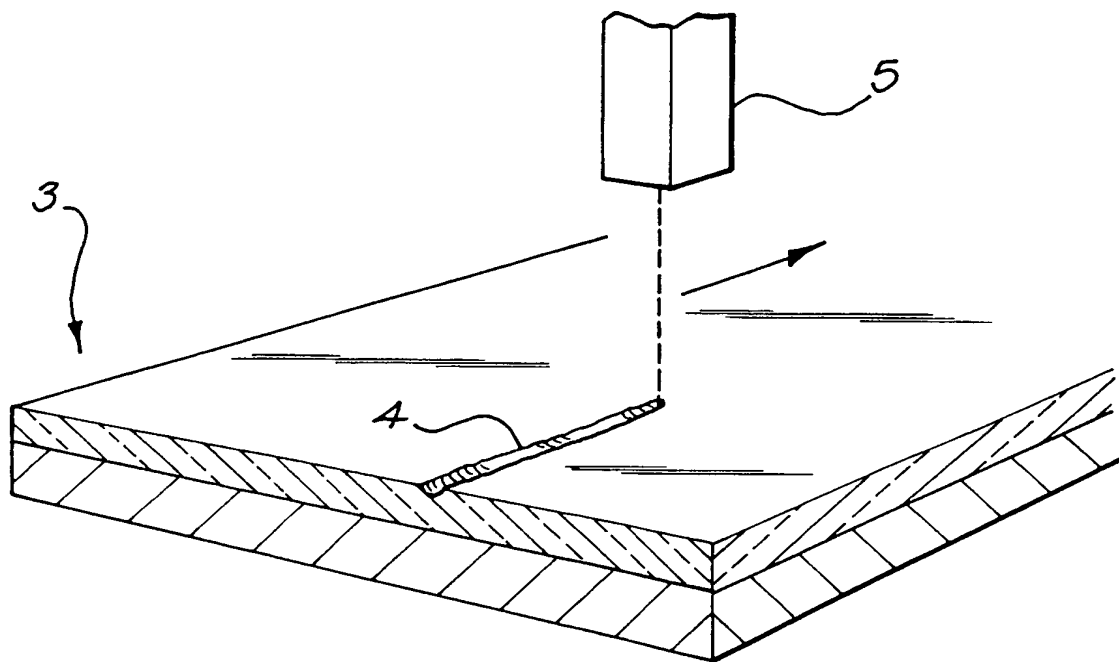
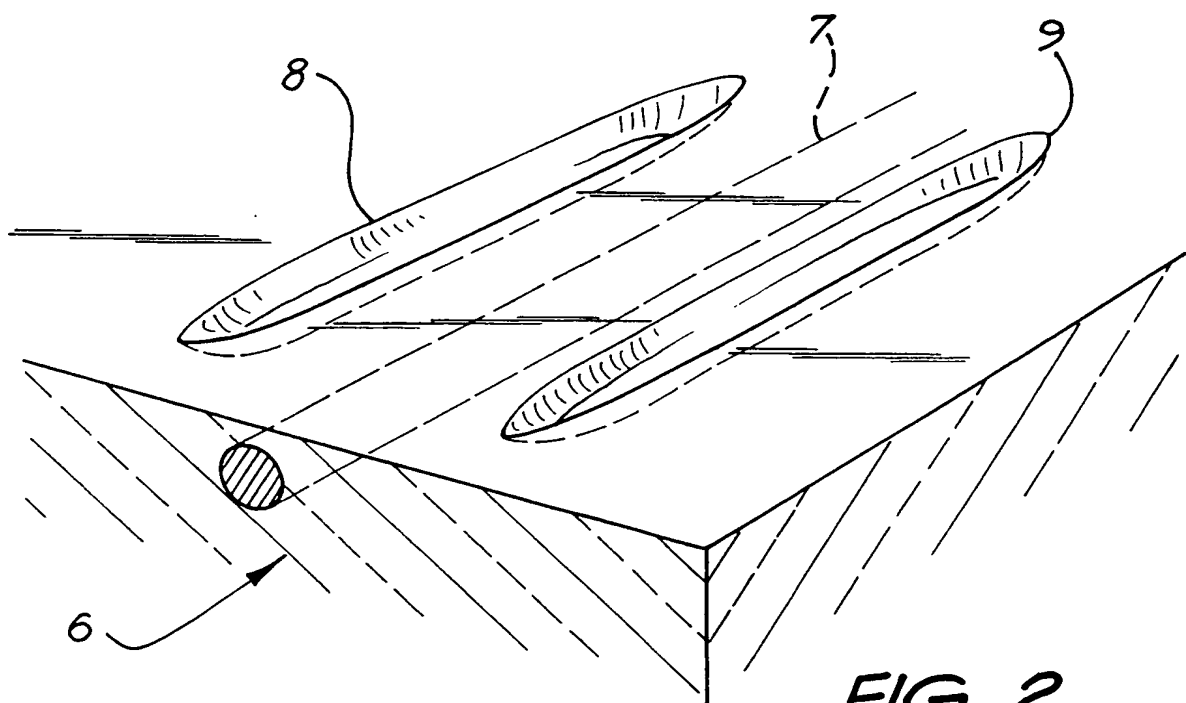
20 17. A method as claimed in any one of the preceding claims wherein the method is utilised to mark the device by way of the ablation.

18. A method as claimed in any one of the preceding claims, wherein the laser comprises a
25 semiconductor laser operating at a wavelength of more than about 1.8 micro metre.

19. A method as claimed in claim 18, wherein the surface of the device comprises SiO₂.

20. A method as claimed in any one of the
30 preceding claims, wherein the method further comprises the step of providing an absorber material to facilitate the heating of the surface of the device.

21. A device incorporating a waveguide, wherein the waveguide has been processed utilising a laser to heat
35 a surface of the device to alter an optical characteristic of the waveguide, wherein the power density of the laser is selected to effect ablation.

**FIG. 1****FIG. 2**

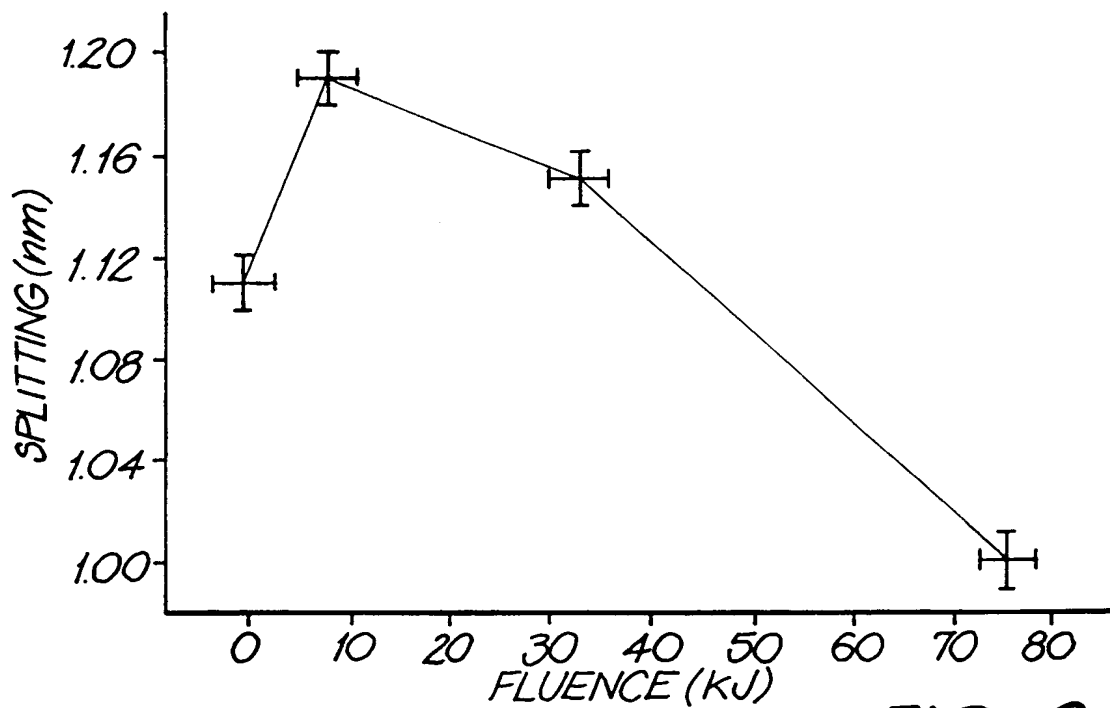


FIG. 3

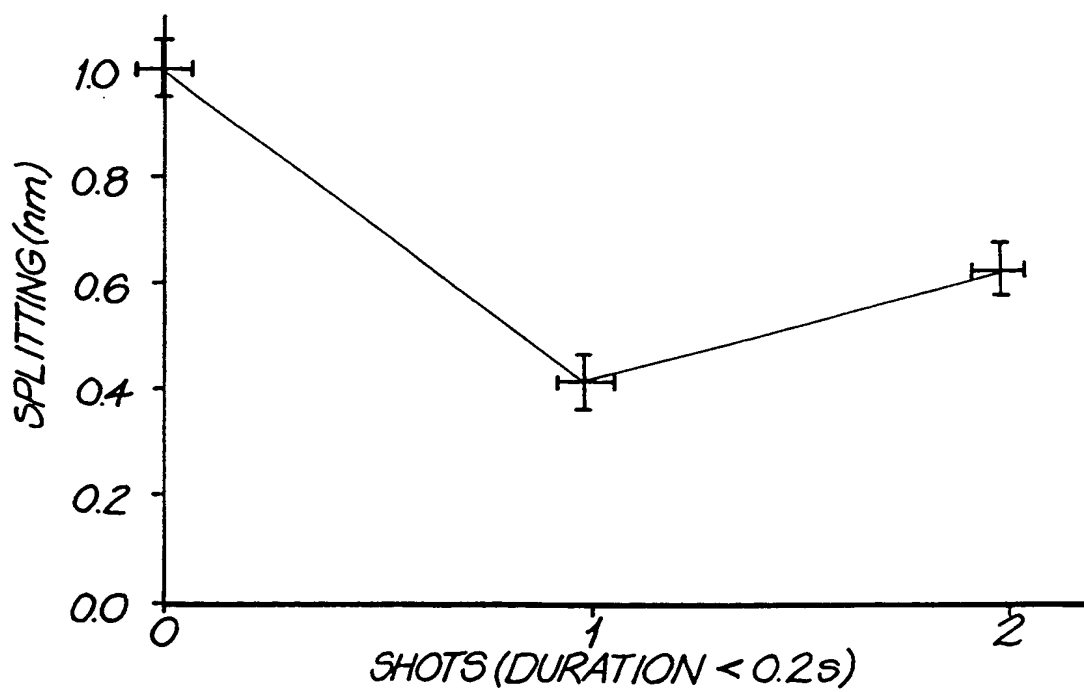


FIG. 4

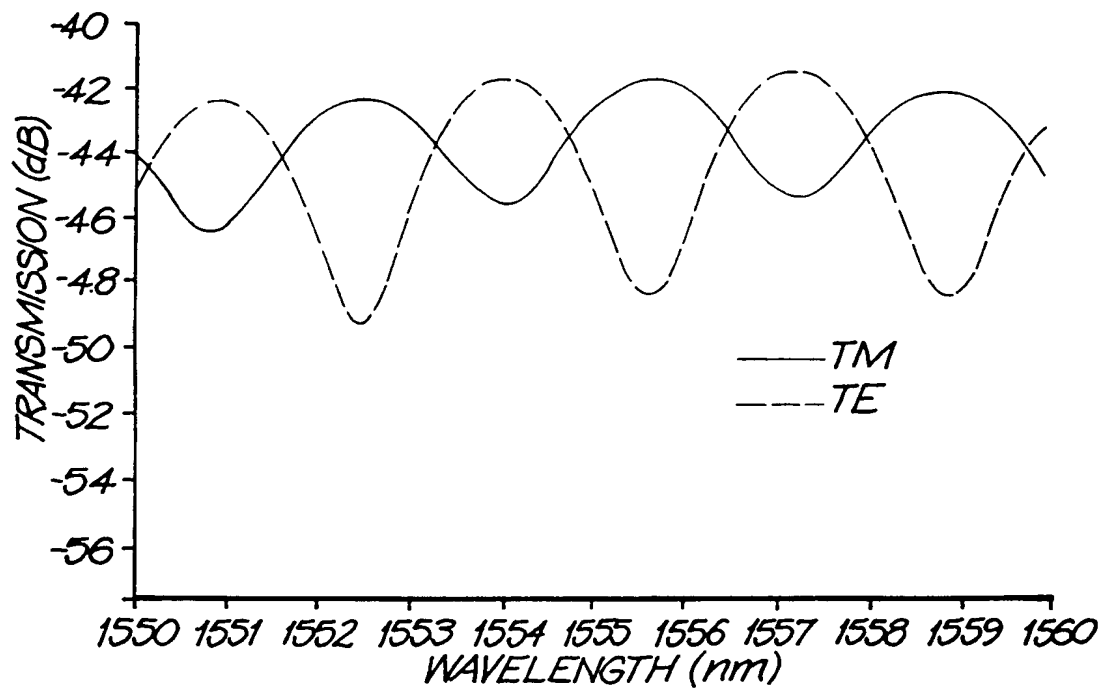


FIG. 5

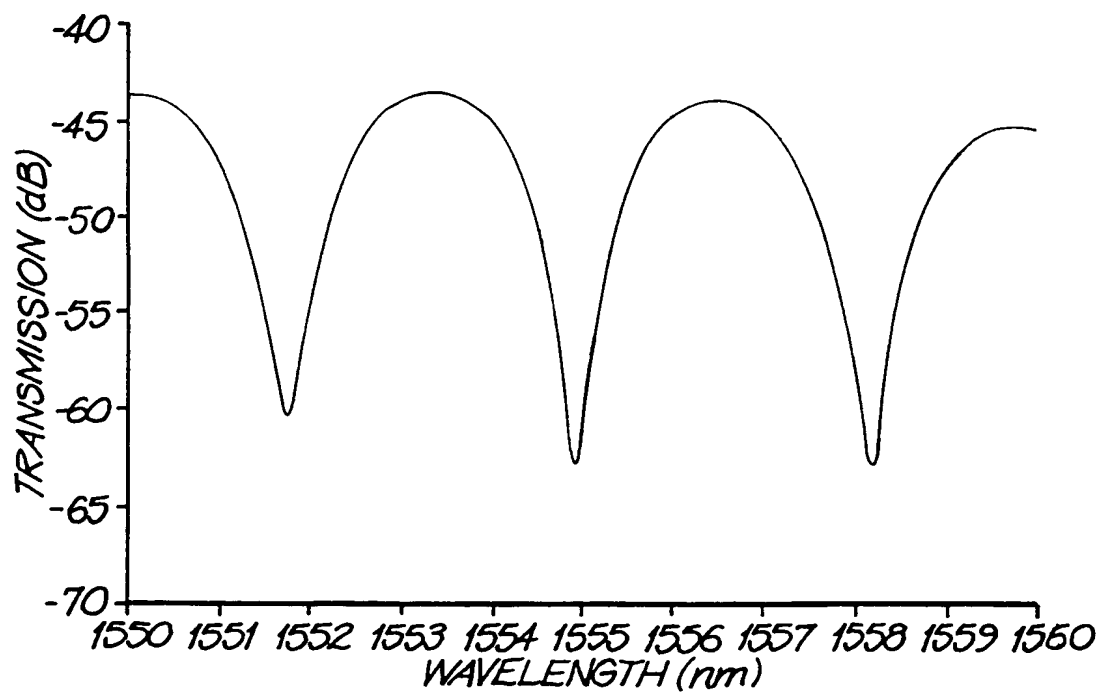


FIG. 6

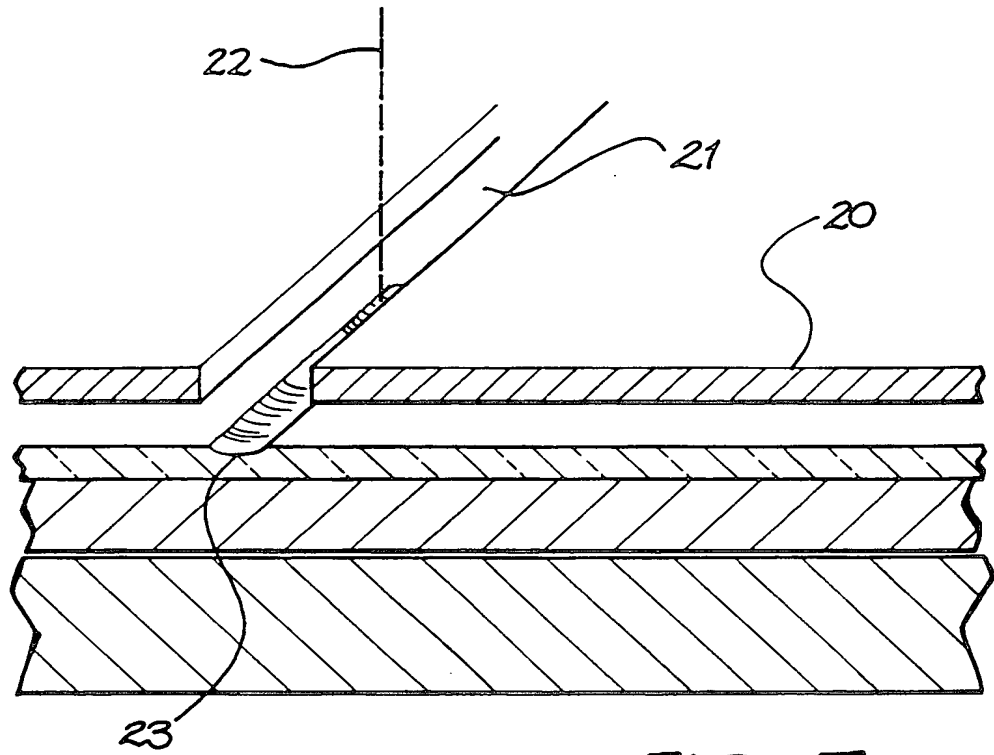


FIG. 7

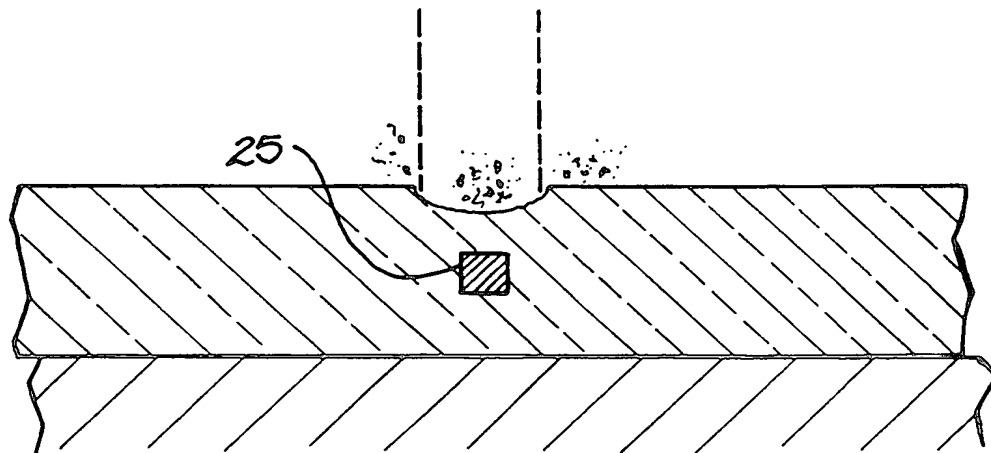


FIG. 8

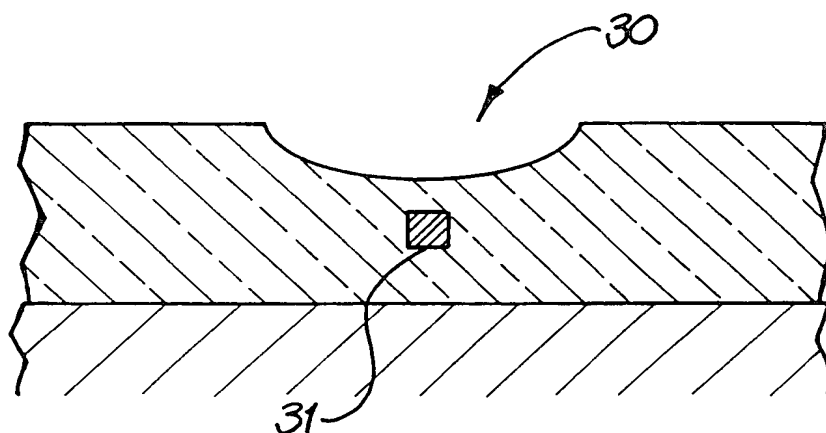


FIG. 9

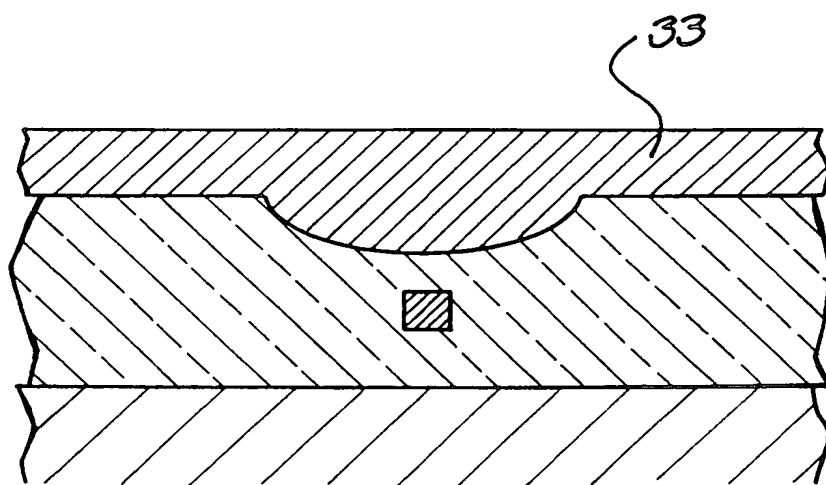
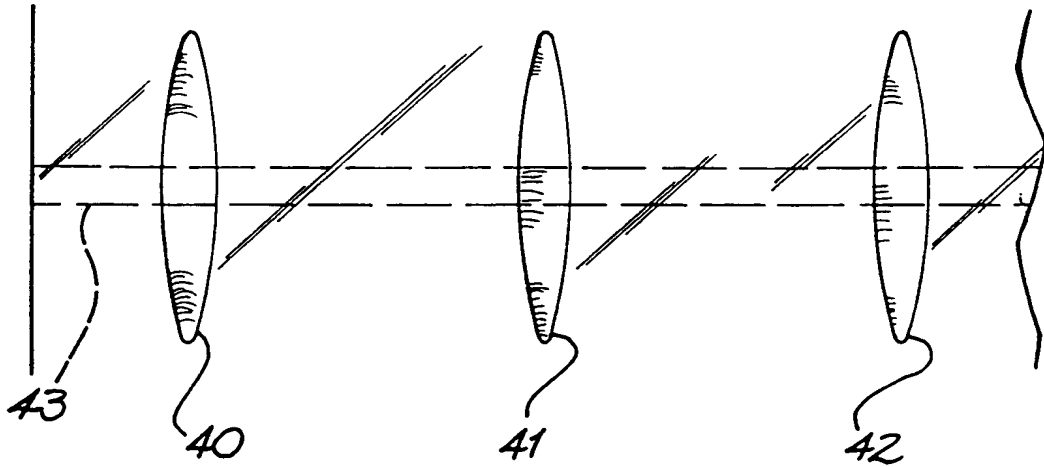


FIG. 10

*FIG. 11*

INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/AU00/00099

A. CLASSIFICATION OF SUBJECT MATTER		
Int. Cl. ⁷ : G02B 6/10, B23K 26/36		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) IPC G02B/IC B23K 26/IC		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) DWPI, JAPIO: laser and heat and ablate (or vaporise, remove, deform, engrave, machine) and (groove or slot or channel) and (stress or strain) and (polarise or birefring)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of relevant passages	Relevant to claim No.
X Y	US 4 978 188 A (KAWACHI <i>et al</i>) 18 December 1990 See whole document	1, 3, 4, 21 2, 3, 6, 9, 11-14, 16, 17, 19
X Y	GB 2 291 208 A (NORTHERN TELECOM LTD) 17 January 1996 See whole document	1, 15, 16, 21 2, 3, 6, 9, 11-14, 16, 17, 19
X Y	US 5 059 763 A (O'BRIEN <i>et al</i>) 22 October 1991 See whole document	1, 9, 12, 21 2, 3, 6, 9, 11-14, 16, 17, 19
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 1 March 2000		Date of mailing of the international search report 14 MAR 2000
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. (02) 6285 3929		Authorized officer DEAN ALLE Telephone No.: (02) 6283 2286

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU00/00099

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 4 626 652 A (BJORK <i>et al</i>) 2 December 1986 See whole document	1, 2, 7-9, 12, 14, 21 2, 3, 6, 9, 11-14, 16, 17, 19
X	US 4 111 520 A (BERNAL) 5 September 1978 See whole document	1, 21
X	US 5 259 061 A (BURNS <i>et al</i>) 2 November 1993 See whole document	1, 21
X	US 5 393 371 A (CHANG <i>et al</i>) 28 February 1995 See whole document	1, 16, 21
Y	US 4 781 424 A (KAWACHI <i>et al</i>) 1 November 1988 See whole document	2, 3, 6, 9, 11-14, 16, 17, 19
Y	US 4 733 927 A (JACKSON <i>et al</i>) 29 March 1988 See whole document	2, 3, 6, 9, 11-14, 16, 17, 19

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU00/00099

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
US	4978188	CA	1317135	EP	297851	JP	1077002
		US	4900112				
GB	2291208	US	5574810				
US	5259061	US	5195163				
US	5393371	CA	2023470	DE	4040512	FR	2656112
		GB	2239102	IT	1241018	JP	3196002
		US	5046808	CA	2075610	EP	527604
		JP	5224045				
US	4781424	CA	1294161	EP	255270	JP	63033710
		JP	63043105	JP	63071808	JP	63147145
		JP	63147114				
US	4733927	EP	202321	IL	76906	WO	8603016
END OF ANNEX							